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The grant The Application of High Resolution Dynamical-Numerical Mod-els as a Tool to Infer Climate Statistics was designed to investigate the use of dynamical-numerical models as a tool for the inference of climate statistics. In addition this grant would develop a procedure that could be implemented at department of defense centers (particularly AFCCC). The main objective of this work was to determine the feasibility of using a dynamical-numerical model for the generation of climate statistics. Other objectives of the pro-posed work were:

(1) Estimate the quality of climate statistics generated from a dynamical-numerical model,
(2) Determine the change in quality of the statistics with varying amounts of observational data assimilated into the model,
(3) Estimate the sensitivity of the statistics to the choice of numerical mode/.
(4) Determine the variations in the quality of the statistics with differing simulation strategies, and
(5) Investigate algorithms to estimate quantities not directly generated by the model (i.e. visibility, icing, etc.).

The major effort of this work involved the simulations for January and July for ten years. The details of the results of these simulations are found in the accompanying technical reports. Here we will mainly address tile objectives listed above.

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Final Report
Saint Louis University
Department of Earth and Atmospheric Sciences

The Application of High Resolution Dynamical-Numerical Models as a Tool to Infer Climate Statistics

Air Force Office of Scientific Research Grant: F49620-95-1-0523

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May 1998

The grant *The Application of High Resolution Dynamical-Numerical Models as a Tool to Infer Climate Statistics* was designed to investigate the use of dynamical-numerical models as a tool for the inference of climate statistics. In addition this grant would develop a procedure that could be implemented at department of defense centers (particularly AFCCC). The main objective of this work was to determine the feasibility of using a dynamical-numerical model for the generation of climate statistics. Other objectives of the proposed work were:

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The major effort of this work involved the simulations for January and July for ten years. The details of the results of these simulations are found in the accompanying technical reports. Here we will mainly address the objectives listed above.

Feasibility of Using a Dynamical-Numerical Model for the Generation of Climate Statistics

The results documented in the technical reports clearly show that using mesoscale models approach has discernible skill in producing climate statistics. Not only where the magnitudes close to observed but the model also captured much of the spatial patterns of the statistics.

The results however, did point to areas which could use improvement. One initial problem dealt with the mass balance over the entire domain. The lateral boundaries where not mass balanced, so the "leak" in the model lead to a -4 mb bias in the pressure field. This problem was corrected for the July simulations and this overall bias was eliminated.

Another set of problems where associated with the mesoscale model formulation. Mesoscale models are typically is concerned with initial values, while the climate simulations are typically concerned with boundary values. Consequently, features not generally of concern in the forecasting problem became important in the climate statistics problem. For example, surface conditions including soil moisture, snow melt, and runoff can become an important factors for climate simulations. Again some modifications of the model were implemented to account for these changes.

Also as noted below, other decisions on simulation strategy has a significant impact on the overall climate statistics.

Overall, the project clearly demonstrated the dynamical-numerical approach for generating climate statistics is a viable solution. In fact, additional DOD funding was obtained to develop and implement this functionality at AFCCC.

Estimating the Quality of Climate Statistics Generated from a Dynamical-Numerical Model

We have developed a methodology for assessing the simulated climate statistics through a comparison with observations. For the simulations, these observations were not assimilated into the simulations to ensure a more robust assessment. The methodology involved 3 components:

1. a comparison of averages, both long term and hourly,

2. a comparison of standard deviations, both long term and hourly, and
3. a comparison of frequency distributions.

While the first two components are standard statistical comparisons, the last component is adapted from geostatistics and is described in the technical reports. A manuscript is currently being prepare for publication describing this approach.

The overall quality of the climate statistics is the combination of each of the 3 components above. From the two long term simulations, the bias (differences in averages) was typically the largest source of error. Most of these differences appear to be related to choices in the modeling strategy as will be discussed later. Occasionally the differences in standard deviations were large, most notably with the dew point temperatures. We expect problems in the moisture physics and surface energy balance in the model are the source of the problem.

The comparison of frequency distributions revealed that the model does a good job with capturing the shape of the distribution if the resolution of the model is taken into account. For example, the raw comparison of the wind field distributions suggest large differences, however if the model resolution is taken into account the model appears to handle wind speeds quite well. As a result we can distinguish differences between the model resolving power and actual model errors.

Determining the Change in Quality of the Statistics with Varying Amounts of Observational Data

After the first set of simulations several features of the simulations became obvious. One of these features is related to ingesting observational data into the simulations. One effect of ingesting observed data into the simulations was the "shock" introduced into the system. This shock became evident in the statistics, where "jumps" in the statistics occurred around the time data ingesting (i.e. jumps occurred at 0 UTC when observed data was assimilated). In fact a new assimilation scheme was developed to reduce this shock to the model. This new scheme was applied to the July simulations and the results show a significant improvement to the statistics.

The ingesting of observational data also had positive impacts. For example, the 40 km simulations which directly incorporated the observational data, compared more favorably with the observations than did the 10 km simulations. Overall, we found that carefully ingested observational data is effective in adjusting the model climatology to the observed climatology (particularly the averages).

Estimating the Sensitivity of the Statistics to the Choice of Numerical Model

The overall results of the simulations are more closely tied to the configuration of the model rather than the actual model itself. For example the planetary boundary layer scheme know as Blackadar scheme was used in the January simulations. In these simulations we typically found a slight cold bias in the results. However, a extended test of the same model with the turbulent kinetic energy scheme resulted in a slight warm bias.

Overall, we found that it is not the model, but the configuration of the model which will control the quality of the simulation statistics. Schemes such as the planetary boundary layer and the convective parameterization have a significant impact on the quality of the statistics. Without additional experience, we feel at this time there is no universal configuration which will provide the best results for all situations.

Determining the Variations in the Quality of the Statistics with Differing Simulation Strategies

After the initial January simulations, we examined the statistics obtained from various subsets of the January simulations. Several sampling scenarios were tried. In most cases, acceptable estimates of the average could be obtained but in all these cases, the observed frequency distributions were poorly simulated. Since the goal of the project was to simulation extreme events as well as averages, further investigations into sampling strategies were not pursued.

Investigating Algorithms to Estimate Quantities Not Directly Generated by the Model

A search of various sources found that there are numerous algorithms which can be incorporated into a post-processing step. Algorithms such as icing, turbulence, visibility, and cloud cover are available from Forecast Systems Laboratory, Phillips Laboratory, and the National Center for Atmospheric Research. Some of these algorithms are based on observational data, however most use of numerical model output in their algorithms.

While numerous algorithms exist, testing and implementing those algorithms was beyond the scope of the current efforts. Additional funding is has been obtained which include the selection and implementation of several of these algorithms.